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# DEVELOPMENT AND PRELIMINARY FIELD TESTING OF AN EXPERIMENTAL DECONTAMINATION APPARATUS

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Port Hueneme, California

Project NY 310 004-1
Technical Note N-222

# DEVELOPMENT AND PRELIMINARY FIELD TESTING OF AN EXPERIMENTAL DECONTAMINATION APPARATUS

17 June 1955

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## SUMMARY

Under a project directive for the development of an effective decontamination apparatus producing a hypochlorite slurry from liquid chlorine, dry chemical and water, there has been designed, fabricated, and tested equipment of the following specifications:

1. No power source is required other than that inherent in the supply water.
2. The equipment has a capacity of 25 gpm of hypochlorite slurry at a supply water pressure of 100 psig. The discharge at this operating condition is suitable for direct spraying.
3. A satisfactory effluent is obtained when the water supply pressure is reduced to as low as 50 psig. However, there is a corresponding reduction in capacity of the apparatus and force of the final spray.
4. The physical and functional characteristics of the equipment are such as to allow the use of a variety of dry chemicals as the starting component.

CONTENTS

## INTRODUCTION

### Background

In keeping with the responsibility of the Bureau of Yards and Docks for the protection of the extensive Naval Shore Establishment in the event of chemical warfare, the Naval Civil Engineering Research and Evaluation Laboratory was assigned the development of an effective decontamination device producing a hypochlorite slurry from liquid chlorine, dry chemical, and water. This work was authorized as a subtask under Project NY 310 004 by RDB Project Card dated 21 August 1953 and assigned to the Laboratory on 8 September 1953.

Prior effort[1] of the Laboratory has resulted in the development of an experimental liquid chlorine infuser under Project NY 300 010 and efforts of the Laboratory were directed towards the adaptation of this infuser into a decontamination apparatus.

### Statement of the Problem

The general requirement is the development of "simple, rugged equipment for the decontamination of contaminated terrain, buildings and equipment, and the collective protection of personnel." The device is to use liquid chlorine and it is desired that the chemical ingredients of the system be "inexpensive, easily stored and packaged, and capable of being kept for long periods of time without deterioration."

The specific requirements established after some preliminary study are as follows:

1. The system is to have a capacity of at least 25 gpm of hypochlorite slurry.
2. No external power source is to be used other than that inherent in the water supply.

1. NAVCERELAB Technical Note N-147, Use, Development and Preliminary Field Testing of Liquid Chlorine Infuser, Model No. 1, Project NY 300 010, by H. M. Donaldson, 26 June 1953.

3. The decontaminant is to have a strength of 4 per cent by weight of available chlorine.

4. The supply water can be at a pressure of 100 psig maximum.

5. The discharge slurry from the apparatus as developed must be at sufficient pressure so that it can be sprayed to a height of at least 10 feet.

## DESCRIPTION OF THE EQUIPMENT DEVELOPED

### Physical Characteristics

Study of commercial dry chemical feeding devices soon disclosed that use of the accepted commercial feeders would require either discarding the specification on external power or converting elaborately to water motors in violation of the requirements of simplicity. Preliminary tests with a hopper type eductor disclosed difficulties in insuring a continuous feed of dry chemical without frequent clogging of the eductor suction. These considerations led to the selection of a liquid suction eductor as the heart of the system and the elimination of any feeding device but the periodic dumping of a sack of dry chemical into a mixing tank. Mixing of the dry chemical and water was accomplished in the mixing tank by diverting a portion of the high pressure supply water to a tank mixing eductor. A schematic of the proposed system (involving no moving parts and being powered by the supply water itself) is shown in Figure 1.

An apparatus based on this system was fabricated for the Laboratory under Contract NOy-73257 by the Fischer & Porter Company. All testing was performed by Laboratory personnel at the Equipment Compound, Point Mugu. Figures 2 and 3 show the unit as received from the fabricator. Pertinent physical characteristics follow:

| | | |
|---|---|---|
| 1. | Over-all height of panel | 5 ft 6 in. |
| 2. | Over-all width of panel | 24 in. |
| 3. | Over-all depth of panel | 18 in. |
| 4. | Diameter of mixing tank | 30 in. |
| 5. | Over-all length of mixing tank | 3 ft 4 in. |
| 6. | Capacity of tank | 95 gal |
| 7. | Size of water supply hose | 1 1/2 in. |
| 8. | Length of water supply hose | 25 ft |
| 9. | Size of discharge hose | 1 1/2 in. |
| 10. | Length of discharge hose | 50 ft |
| 11. | Size of discharge nozzle | 1 1/2 in. - $30^{\circ}$ cone |
| 12. | Size of chlorine inlet | 1/2 in. |
| 13. | Size of proportioning eductor | 1 1/2 in. x 1 1/2 in. x 1 1/4 in. |
| 14. | Size of tank mixing eductor | 1/2 in. |

Auxiliary chlorine dispensing equipment was designed and fabricated by the Laboratory. This apparatus is shown in Figure 4 and allows the mounting and inverting of 150-pound chlorine cylinders. Figure 5 shows the arrangement of the assembled equipment. Apparatus shown in Figure 4 will be required when using 100- or 150-pound chlorine cylinders. If the chlorine is available in ton containers, inversion of the container is not required owing to a valve arrangement allowing flow of liquid chlorine while the container is horizontal.

## Functional Characteristics

1. The apparatus is operated in the following manner:

a. An initial concentration of dry chemical in water is prepared in the cylindrical tank just prior to decontamination operations by mixing the required number of full sacks of chemical into a measured amount of water. This preliminary mixing may be accomplished by means of a wooden paddle after the ingredients have been introduced or, if a water meter is available in the water supply system, by operating the apparatus with both the chlorine and eductor suction valves closed and directing the discharge nozzle into the mixing tank until the proper amount of water has been introduced.

b. As soon as the initial chemical mixture has been prepared in the mixing tank, the discharge hose shall be directed at the area to be decontaminated, the eductor suction valve shall be opened, the water inlet valve adjusted to 25 gpm and the make-up water and eductor suction flow equalized at a prescribed rate of flow to maintain the operating level in the mixing tank.

c. As soon as operating conditions are stabilized as indicated by steady flowrater readings and a steady flow from the discharge nozzle, the valves in the chlorine line shall be opened in order, starting at the cylinder and working towards the chlorine flow adjusting valve on the panel. The rate of chlorine flow shall be adjusted to allow a discharge of 4 per cent available chlorine by weight. If the introduction of the chlorine alters the previous water and slurry rates, these shall be readjusted to the original values.

d. At prescribed intervals of time, or for each prescribed gallonage of fresh supply water, a new sack of dry chemical shall be added to the mixing tank. This procedure shall be continued until decontamination operations cease.

e. As each chlorine cylinder is emptied, it shall be closed off from the chlorine line and a fresh cylinder opened into the line. As soon as a chlorine cylinder is closed off from the line, the cylinder valve shall be closed, the cylinder removed from its station, and a full cylinder mounted in its place. Under certain operating conditions, ‹ 'fficulty may be experienced in maintaining the desired chlorine flow frcm one cylinder at a time. In that case, chlorine may be manifolded from .w‹ ;ylinders simultaneously. However, this can be a dangerous practice if the contents of one cylinder are transferred into the second cylinder bringing it above its rated weight when the apparatus is shut down. When manifolding is required, it is necessary to keep a check on the chlorine weight in each cylinder.

2. The apparatus is closed down in the following manner.

a. The chlorine valve at the chlorine cylinder is closed down but the decontamination apparatus is to continue in operation until the chlorine in the pipe lines has been evacuated and has reacted with the dry chemical and water mixture. Nitrogen, if available, shall then be used in place of chlorine to flush out the system and the water supply valve is then closed.

b. If decontamination operations are to be secured for a long period of time, the chlorine valves at the dispenser station shall be closed, the cylinders disconnected and reinverted. The mixing tank shall be emptied of its contents and hosed down with fresh water.

3. This operating technique has been developed on the basis of an analysis of the proposed system which is given in the Appendix. The operating variables were prepared in alignment chart form for easy reference. The chart for hydrated lime appears as Figure 6. A similar chart for use with quicklime is included as Figure 7.

## TESTS

### Preliminary Tests Without Chlorine

As soon as the apparatus could be set up after being received from the fabricator, it was operated with $Ca(OH)_2$ and water in order to check whether adequate control of the concentration of lime in water was obtained by the procedure of feeding chemical in full bag units. The unit was operated for approximately six minutes at a discharge rate of 25 gpm, tank make-up water rate of 6 gpm, slurry flow from tank of 6 gpm, and with 32 gal of water in the mixing tank. This operating condition was chosen in accordance with Figure 6. Periodic analysis of the concentration of the milk of lime was obtained by titration of the $Ca(OH)_2$ with standard HCl using phenolphthalein as an indicator. The results of the analysis were as follows:

| Sample no. | Concentration lb/gal |
|---|---|
| 1 | 0.486 |
| 2 | 0.395 |
| 3 | 0.340 |
| 4 | 0.365 |
| 5 | 0.360 |
| 6 | 0.350 |
| 7 | 0.340 |
| 8 | 0.360 |
| 9 | 0.380 |

The theoretical concentration (see Appendix) is 0.376 lb/gal.

## Preliminary Tests With Chlorine

Initial attempts to operate the device with chlorine led to the modification of the apparatus to the extent of changing the proportioning eductor to 1 in. x 1 1/4 in. x 1 1/4 in. and raising the mixing tank approximately two feet above ground level as shown in Figure 8. On 3 March 1955, the apparatus was operated with $Ca(OH)_2$ and chlorine for twenty minutes at the following conditions:

| | | |
|---|---|---|
| Supply water pressure | 110 psi | |
| Supply water flow rate | 25 gpm | |
| Tank make-up water flow | 6 gpm | see Figure 6 |
| Slurry flow from tank | 6 gpm | |
| Water maintained in tank | 32 gal | |
| Chlorine flow rate* | 400 lb/hr | |

*As indicated on chlorine flowrater, calibrated at 68 F, the theoretical flow is 540 lb/hr (see Appendix). The manifolding of two 150-lb cylinders was required to maintain this flow.

Periodic analysis of the hypochlorite discharge gave the following results:

| Sample no. | Per cent available chlorine by weight |
|---|---|
| 1 | 5.5 |
| 2 | 5.0 |
| 3 | 4.7 |
| 4 | 5.1 |
| 5 | 5.0 |
| 6 | 4.4 |

The discharge of the hypochlorite (see Figure 9) was demonstrated to be of sufficient velocity to satisfy the performance specification for the equipment; the inability of the three-station chlorine dispensing apparatus to allow uninterrupted chlorine flow from two cylinders at a time stopped operations after the two cylinders were emptied. Attempts to start up again after the two cylinders were replaced were not successful owing to clogging of the eductor suction and collapse of the suction hose from the tank caused by the settling out of the lime during the idle period. Provision was then made for allowing uninterrupted chlorine flow by modification of the chlorine dispensing apparatus prior to the continuation of tests. Replacement of the suction hose for one less susceptible to collapse was also indicated, as well as the need to stir the mixing tank by hand during any brief shut-down period.

The hypochlorite slurry discharge during these tests was of a distinct red color owing to the presence of iron, probably in the form of a ferrate. However, the concentration of impurities that caused various colors in bleach liquor is insignificant insofar as the quality or stability of the product is concerned.

While the chlorine dispensing rack for the 150-pound cylinders was being modified to allow uninterrupted operation, further tests were run with the liquid chlorine being supplied from a ton container. The apparatus was run continuously, using $Ca(OH)_2$ as before, for a period of 87 minutes on 24 March 1955 and again for 64 minutes on 25 March 1955. The operating conditions were as follows:

| | 24 March | | 25 March | |
|---|---|---|---|---|
| Supply water pressure | 90 psi | Caused by poor ignition of the water pump engine. | 100 psi | |
| Supply water flow rate | 24 gpm | | 25 gpm | see Figure 6 |

| | 24 March (contd) | 25 March (contd) | |
|---|---|---|---|
| Tank make-up water flow | 6 gpm | 6 gpm | see Figure 6 |
| Slurry flow from tank | 6 gpm | 6 gpm | |
| Water maintained in tank | 32 gal | 32 gal | |
| Chlorine flowrater reading | 300 to 200 | 350 to 250 | |
| Chlorine pressure | 20 psig | 20 psig to 10 psig | |
| Eductor discharge pressure | 18 psig | 18 psig to 6 psig | |

Periodic analysis of the hypochlorite discharge gave the following results:

> Per cent available chlorine by weight for 25 samples tested on 24 March (see Figure 10).
>
> Per cent available chlorine by weight for 12 samples tested on 25 March (see Figure 11).

The tests were characterized by a somewhat pulsating discharge of the effluent and erratic chlorine flowrater indications. It was surmised that complete mixing of the chlorine and milk of lime was not being obtained and pockets of chlorine gas were being discharged. This would also account for the large range in available chlorine indications of the samples. Provision was then made for a modification of the chlorine injector to insure improved mixing. The modification provided for a longer chlorine injector and a closer approach to true counterflow mixing by arranging the holes in the injector to introduce the chlorine so as to oppose the swirl of the slurry.

## Acceptance Test of Apparatus

On 4 April 1955, the apparatus was operated continuously for 64 minutes with the modified injector. The operating conditions were as follows:

| | | |
|---|---|---|
| Supply water pressure | 100 psig | |
| Supply water flow rate | 25 gpm | see Figure 6 |
| Tank make-up water flow rate | 6 gpm | |
| Slurry flow from tank* | 6 gpm | |
| Water maintained in tank | 32 gal | |
| Chlorine flowrater reading** | 200 | |
| Chlorine pressure | 20 psig | |
| Eductor discharge pressure | 20 psig | |

*Flowrater reading was varied from 6 to 11 gpm during course of run in order to maintain operating level in mixing tank.
**Chlorine flowrater was found to be improperly calibrated. Six hundred lb of chlorine were used during course of run.

Periodic analysis of the hypochlorite discharge gave the results charted in Figure 12. The tests were characterized by a much steadier discharge from the hose and a marked improvement in stability of all meter readings. The chlorine during these tests was provided by the dispenser (see Figure 4) modified to accommodate four 150-lb cylinders. On the basis of this test, the equipment was considered to have fulfilled the performance specifications of Contract NOy-73257.

### Operational Tests

On 5 May 1955, tests were conducted (with hydrated lime and chlorine) to determine the operating characteristics of the equipment with reduced supply water pressure. During the course of these tests, the pressure of the supply water was reduced in increments from 100 psig until the apparatus failed to produce an acceptable effluent from the discharge hose. As indicated in Figure 13, reduction of supply water pressure is accompanied by a corresponding reduction in capacity of the equipment requiring adjustments in tank make-up water flow. The discharge at these reduced pressures is characterized also by a reduction in spray velocity.

## CONCLUSIONS

As a result of the work to date, there has been proposed, fabricated, and demonstrated an inexpensive chemical decontamination apparatus, using liquid chlorine and dry chemicals, and fulfilling the following specifications:

a. A capacity of at least 25 gpm of hypochlorite slurry (at a supply water pressure of 100 psig).

b. No external power source other than that inherent in the inlet water.

c. An effluent strength of at least 4 per cent by weight of available chlorine, with this strength under the control of the operator within practical limits.

d. No moving parts.

e. Final discharge capable of being sprayed to a height of at least 10 ft.

The basic system, Figure 1, can be fabricated at higher discharge capacities than the 25 gpm selected for the initial development, if analysis of the operating requirements indicates that such is required. The strength of the effluent need be limited only by the flow characteristics from the chlorine container. The system allows the use of a variety of dry chemicals as the starting component. A satisfactory effluent is obtained when the water supply pressure is reduced to as low as 50 psig. However, there is a corresponding reduction in capacity of the apparatus and force of the final spray.

## RECOMMENDATIONS

It is recommended that, upon verification of the operational requirements forming the basis of this development, the design features and operating techniques embodied in this experimental apparatus be incorporated in a prototype apparatus aimed at further simplification and elimination of all accessories used merely to facilitate experimental observations. Such prototype apparatus can then be issued for evaluation by the other services and the training of the field forces.

## APPENDIX

### COMPUTATIONS OF CHEMICAL FEEDING AND DISSOLVING SYSTEM

It is desired to obtain a solution containing 4.0 per cent available chlorine by mixing lime with water and infusing liquid chlorine into the resultant suspension. The chemical reactions are as follows:

$$2CaO + 2H_2O \rightarrow 2Ca(OH)_2$$
$$2Ca(OH)_2 + 2Cl_2 \rightarrow CaCl_2 + Ca(OCl)_2 + 2H_2O$$

Knowing the atomic weights of the elements involved, i.e.,

| | |
|---|---|
| Cl . . . . . . . . | 35.457 |
| O . . . . . . . . | 16.000 |
| Ca . . . . . . . . . | 40.08 |
| H . . . . . . . . | 1.008 |

the relative masses involved in the final reaction can be determined.

$$2CaO + 2H_2O \rightarrow 2Ca(OH)_2$$
$$112.160 + 36.032 = 148.192$$

$$2Ca(OH)_2 + 2Cl_2 \rightarrow CaCl_2 + Ca(OCl)_2 + 2H_2O$$
$$148.192 + 141.828 = 110.994 + 142.994 + 36.032 = 290.020$$

The relative mass of the chlorine in the final products is 141.828 and in order to be 4.0 per cent of a solution, the relative mass of the solution must be $\frac{141.828}{.04} = 3545.7$. This will require the dilution of the products of the chemical reaction with 3545.7 - 290.02 = 3255.68 parts of additional water giving a total of 3255.68 + 36.032 = 3291.712 parts of water for 112.160 parts of lime.

Thus

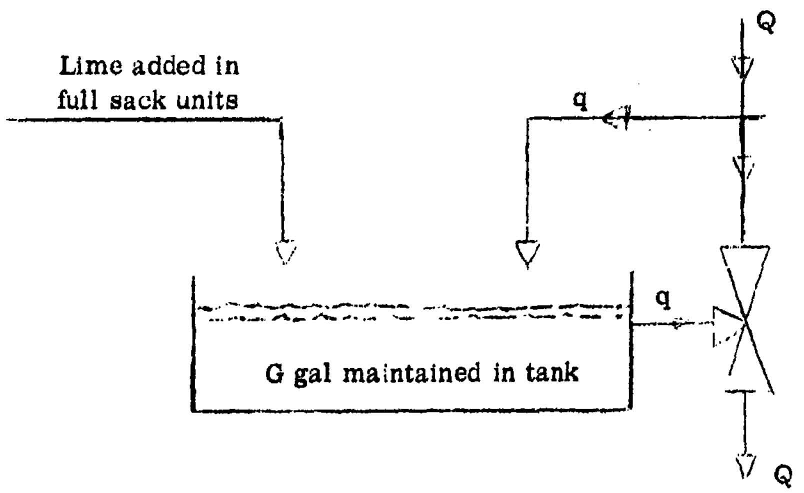
$$\frac{112.160 \text{ lb lime}}{3291.712 \text{ lb water}} = \frac{112.160 \times 62.4 \times 231}{3291.712 \times 1728} = 0.285 \frac{\text{lb lime}}{\text{gal water}}$$

and

$$\frac{141.828 \text{ lb chlorine}}{3291.712 \text{ lb water}} = 0.359 \frac{\text{lb chlorine}}{\text{gal water}}$$

are the theoretical concentrations of the reaction.

A schematic diagram of the proposed system is shown below




In addition to symbols explained in the sketch above, let

n = number of 60-lb sacks of lime added to the G gal of water in the mixing tank prior to the start of a run.

c = lime concentration in $\frac{\text{lb}}{\text{gal water}}$ existing in the mixing tank after operating for t minutes.

C = lime concentration in $\frac{\text{lb}}{\text{gal water}}$ existing at the eductor discharge after operating for t minutes.

If the q gal/min flow to the mixing tank is sufficient to maintain thorough mixing, the amount of lime in the mixing tank after t minutes of operation = cG.

In order that amount of water in the mixing tank be constant, it is necessary that water rate of eductor suction = q and the amount of lime drawn out of the mixing tank since the start of operations = $\int_0^t cq\,dt$.

Thus

$$cG = 60n - \int_0^t cq\,dt \tag{1}$$

and since the lime drawn out of the mixing tank must pass out the eductor discharge

$$\int_0^t cq\,dt = \int_0^t CQ\,dt \tag{2}$$

equation (2) can be expressed as

$$cq = CQ \tag{3}$$

or

$$c = \frac{CQ}{q} \tag{4}$$

Then substituting (4) in (1) and solving for the concentration of the eductor discharge, we have

$$C = \frac{60n}{GQ}\,q - \frac{q}{G}\int_0^t C\,dt. \tag{5}$$

Differentiating in respect to t gives

$$\frac{dC}{dt} = -\frac{qC}{G} \tag{6}$$

$$\frac{dC}{C} = -\frac{q\,dt}{G} \tag{7}$$

$$\log_e C = -\frac{qt}{G} + \log_e k \tag{8}$$

$$C = ke^{-\frac{qt}{G}} \tag{9}$$

when

$$t = o, \ C = C_0 = \frac{c_0 q}{Q} = \frac{60nq}{GQ}.$$

Therefore,

$$k = \frac{60nq}{GQ}$$

and

$$C = \frac{60nq}{GQ} e^{-\frac{qt}{G}}. \quad (10)$$

Letting $m = \frac{Q}{q}$ , a characteristic of eductor performance, we have

$$C = \frac{60n}{mG} e^{-\frac{Qt}{mG}}. \quad (11)$$

Equation (11) allows the development of an expression for the time $t_c$ when the concentration at the eductor discharge reaches the theoretical value (see page 11).

Thus

$$0.285 = \frac{60n}{mG} e^{-\frac{Qt_c}{mG}}. \quad (12)$$

At this time a 60-lb sack of lime must be added to the mixing tank and in order for the cycle to be repeated, the addition of this sack of lime must bring the concentration back up to the value at the start of the first cycle.

Therefore,

$$c_c G + 60 = 60n \quad (13)$$

where $c_c$ = concentration in mixing tank at $t_c$.

From equation (4) $c_c = 0.285m$ and (13) becomes

$$0.285mG = 60(n-1)$$

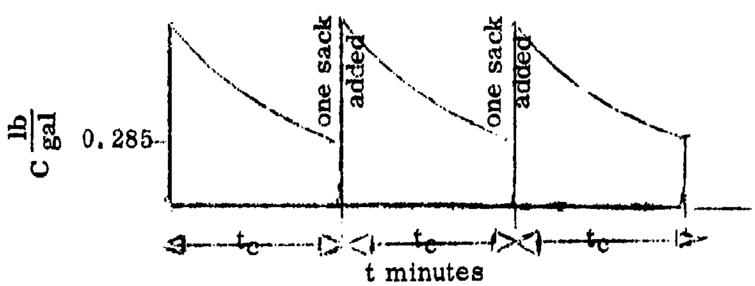
or

$$mG = \frac{60(n-1)}{0.285}. \quad (14)$$

Substituting (14) into (12) gives

$$Qt_c = \frac{60(n-1)}{0.285} \log_e \frac{n}{n-1} . \tag{15}$$

Equations (14) and (15) embody the required design criteria for the proposed system which will have a periodic lime concentration vs time curve such as shown below.




The rate of infusion of chlorine shall be maintained at the theoretical 4.0 per cent concentration (see page 10). The excess lime will act as a buffer and a thickening agent of the final slurry.

Substitution of the numerical values for n allows the determination of the required characteristics of the proposed system.

| When | From equation (14) | From equation (15) |
|---|---|---|
| $n = 2$ | $mG = 211$ | $Qt_c = 146$ |
| $n = 3$ | $mG = 422$ | $Qt_c = 171$ |
| $n = 4$ | $mG = 633$ | $Qt_c = 180$ |

$n$ = number of 60-lb sacks of quicklime added to the G gal of water in the mixing tank prior to the start of a run.

$G$ = gal of water maintained in mixing tank during operation of the system.

$m = \frac{Q}{q}$ = proportioning ratio of eductor, a feature of the eductor design and the operating pressures.

$Q$ = water flow rate gal/min at system inlet.

$Q$ = water flow rate gal/min at eductor discharge.

$q$ = water flow rate gal/min at eductor suction.

$q$ = water flow rate gal/min to mixing tank.

$t_c$ = interval in minutes before adding a new 60-lb sack of quicklime to the mixing tank to maintain 4.0 per cent available chlorine in the final slurry.

The above table denotes, for example, that if three sacks of quicklime are added to 60 gal of water in the mixing tank prior to the start of operations, the eductor must be chosen and adjusted so that $m = \frac{Q}{q}, = \frac{422}{G} = \frac{422}{60} = 7.03$ and a new sack of lime must be added to the mixing tank for each 171 gal of high pressure water used during the course of operations.

If the starting point of the process is hydrated lime, $Ca(OH)_2$, instead of quicklime, CaO, then since the molecular weight of $Ca(OH)_2$ is 74.096 in comparison with 56.080 for CaO, there will be required

$$0.285 \times \frac{74.096}{56.080} = \frac{0.376 \text{ lb hydrated lime}}{\text{gal water}}.$$

Hydrated lime comes in 50-lb units instead of 60-lb units; therefore, equations (14) and (15) become

$$mG = \frac{50(n-1)}{0.376} \tag{16}$$

and

$$Qt_c = \frac{50(n-1)}{0.376} \log_e \frac{n}{n-1} \tag{17}$$

where

$n$ = the number of 50-lb sacks of hydrated lime added to the G gal of water in the mixing tank prior to the start of a run.

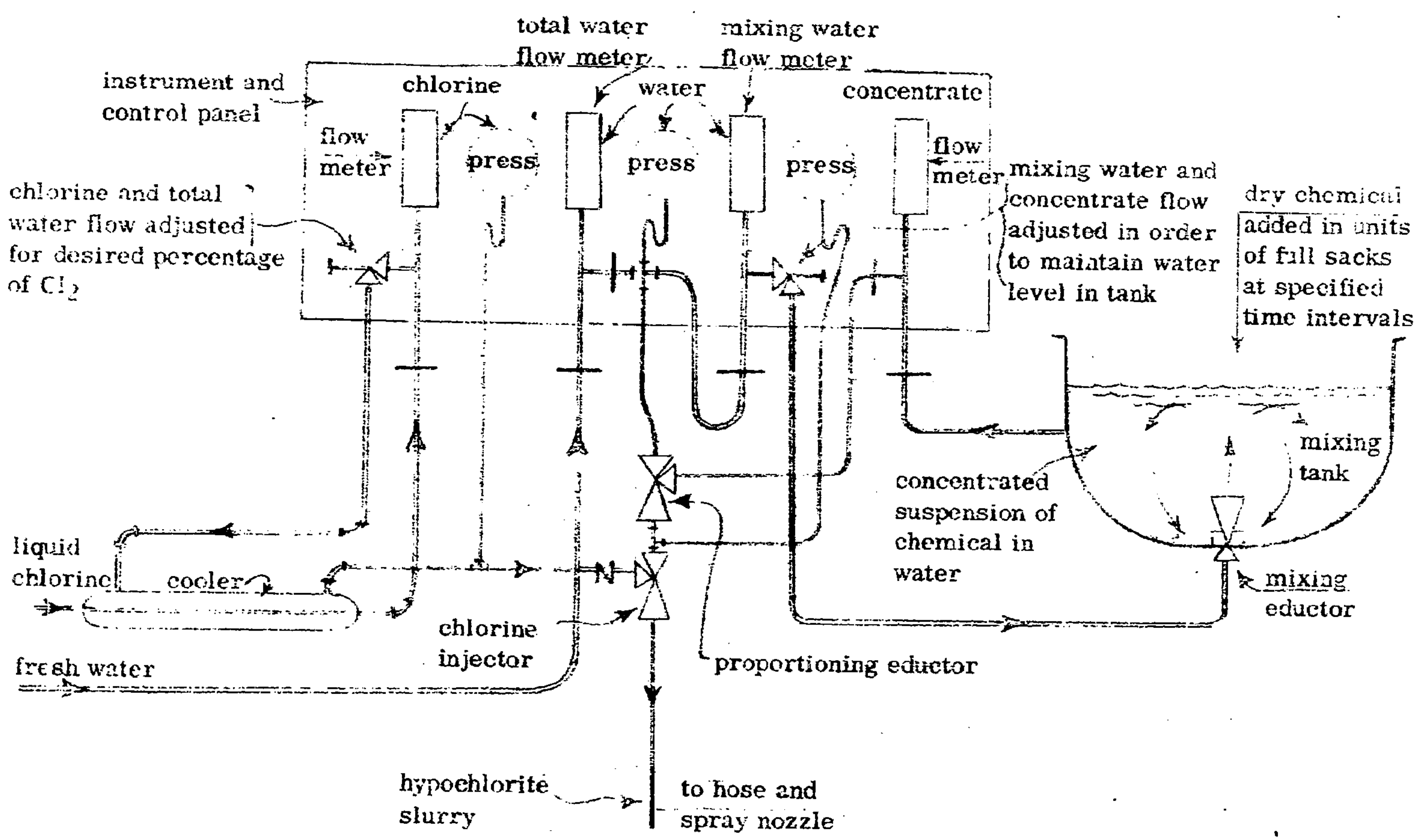
and

$t_c$ = interval in minutes before adding a new 50-lb sack of hydrated lime to the mixing tank after the start of operations,

and when

| | | |
|---|---|---|
| $n = 2$ | $mG = 133$ | $Qt_c = 92.2$ |
| $n = 3$ | $mG = 266$ | $Qt_c = 108.0$ |
| $n = 4$ | $mG = 400$ | $Qt_c = 114.0$ |
| $n = 5$ | $mG = 533$ | $Qt_c = 119.0$ . |

Thus, if four sacks of hydrated lime are added to 60 gal of water in the mixing tank prior to the start of operations, the eductor must be chosen and adjusted so the $m = \frac{Q}{q} = \frac{400}{G} = \frac{400}{60} = 6.67$ and a new sack of hydrated lime must be added to the mixing tank for each 114 gal of high pressure water used.




Specifications

Water supply pressure may be no greater than 100 psig.
Capacity of system to be no less than 25 gal per min.
Chlorine is to be 4.0% by weight of final discharge.

Discharge of hypochlorite to be of sufficient velocity to spray 10 ft high.
No additional power to be utilized other than that of water supplied.

Figure 1. Schematic of proposed system for the preparation of hypochlorite slurry.

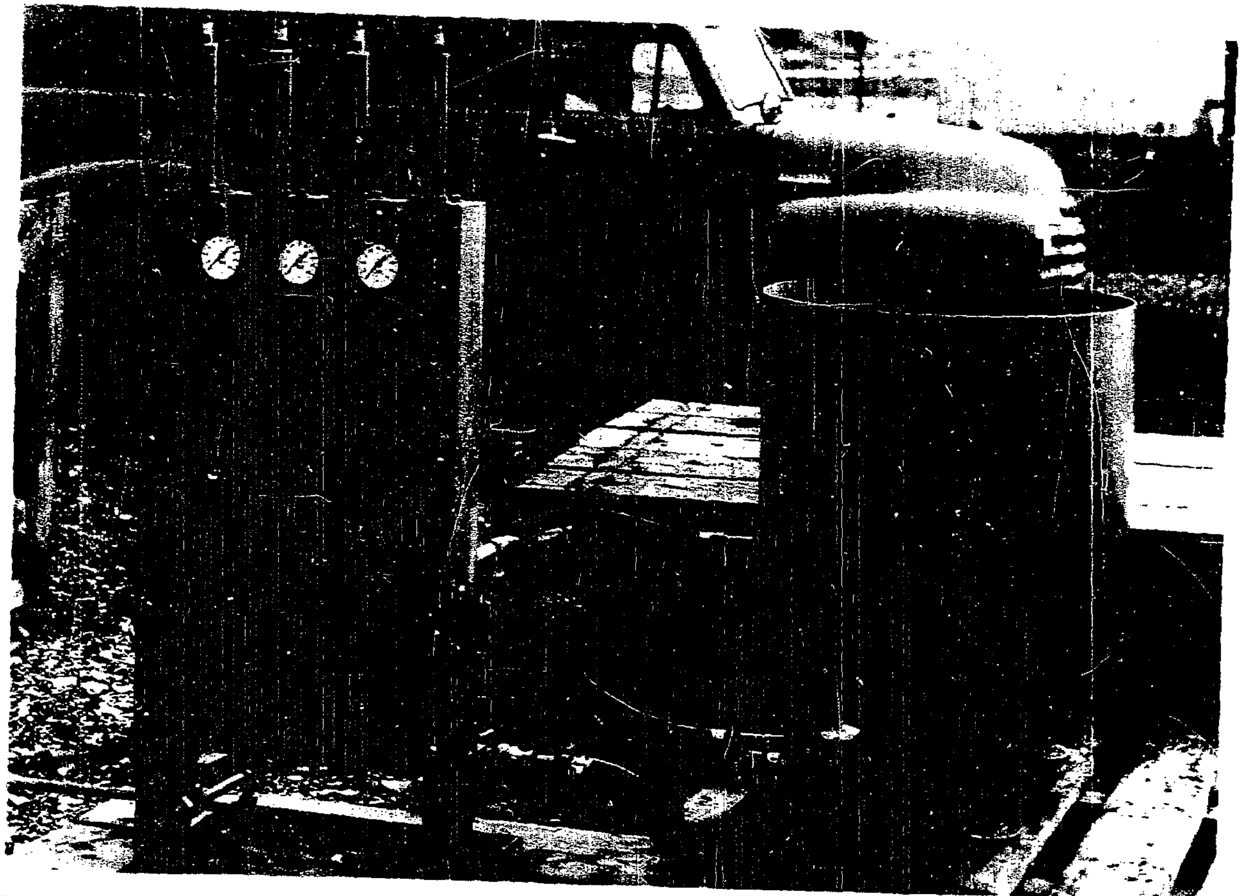


Figure 2. Fischer and Porter chemical mixing and chlorine infusing apparatus.

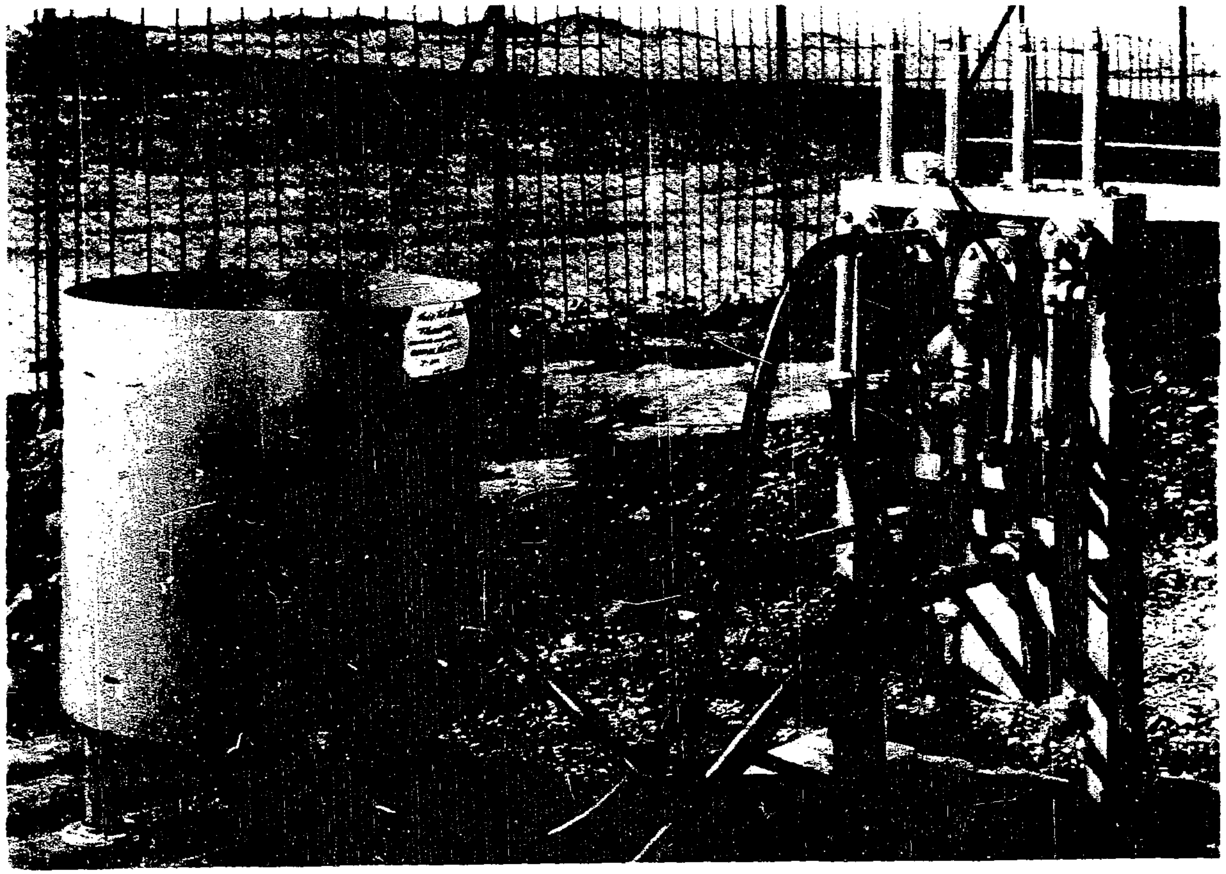


Figure 3. Rear view of Fischer and Porter mixing apparatus (power from water pressure).

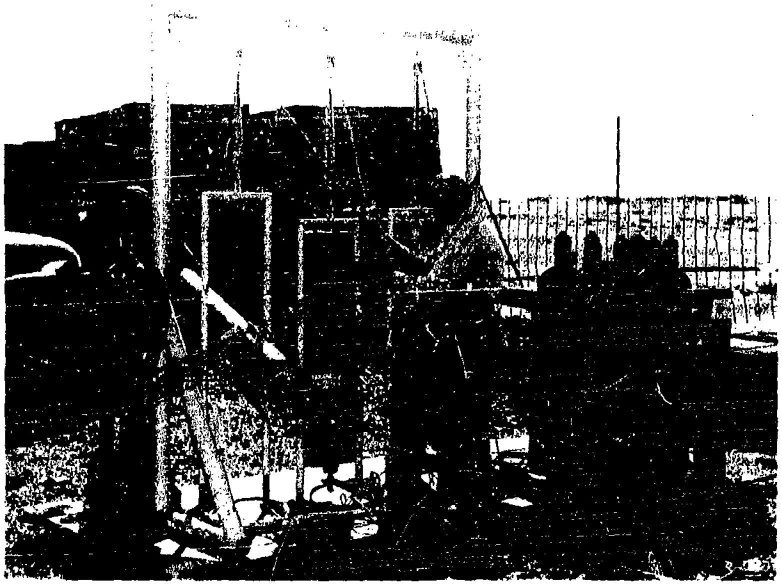


Figure 4. Obtaining liquid chlorine from inverted cylinder bottle (lines later flushed with nitrogen).

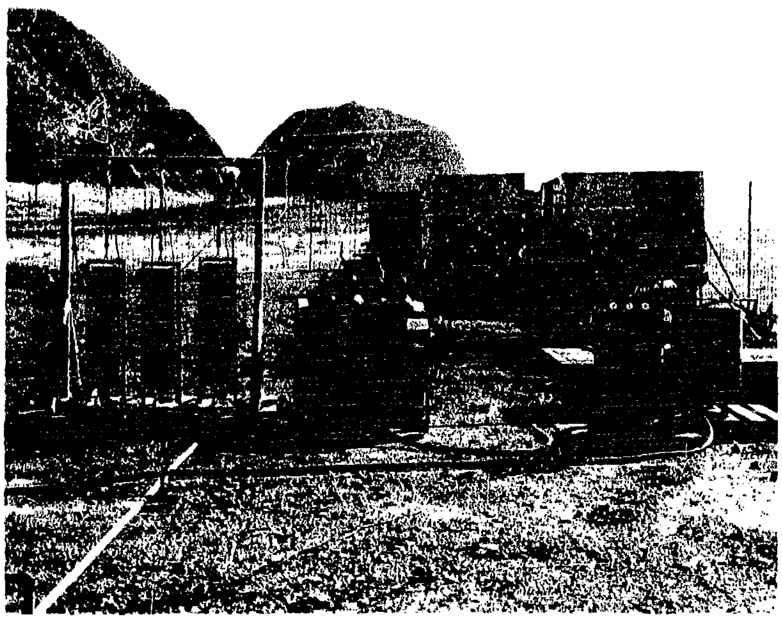


Figure 5. Decontamination apparatus showing chlorine cylinders, cylinder storage, and Fischer-Porter unit.

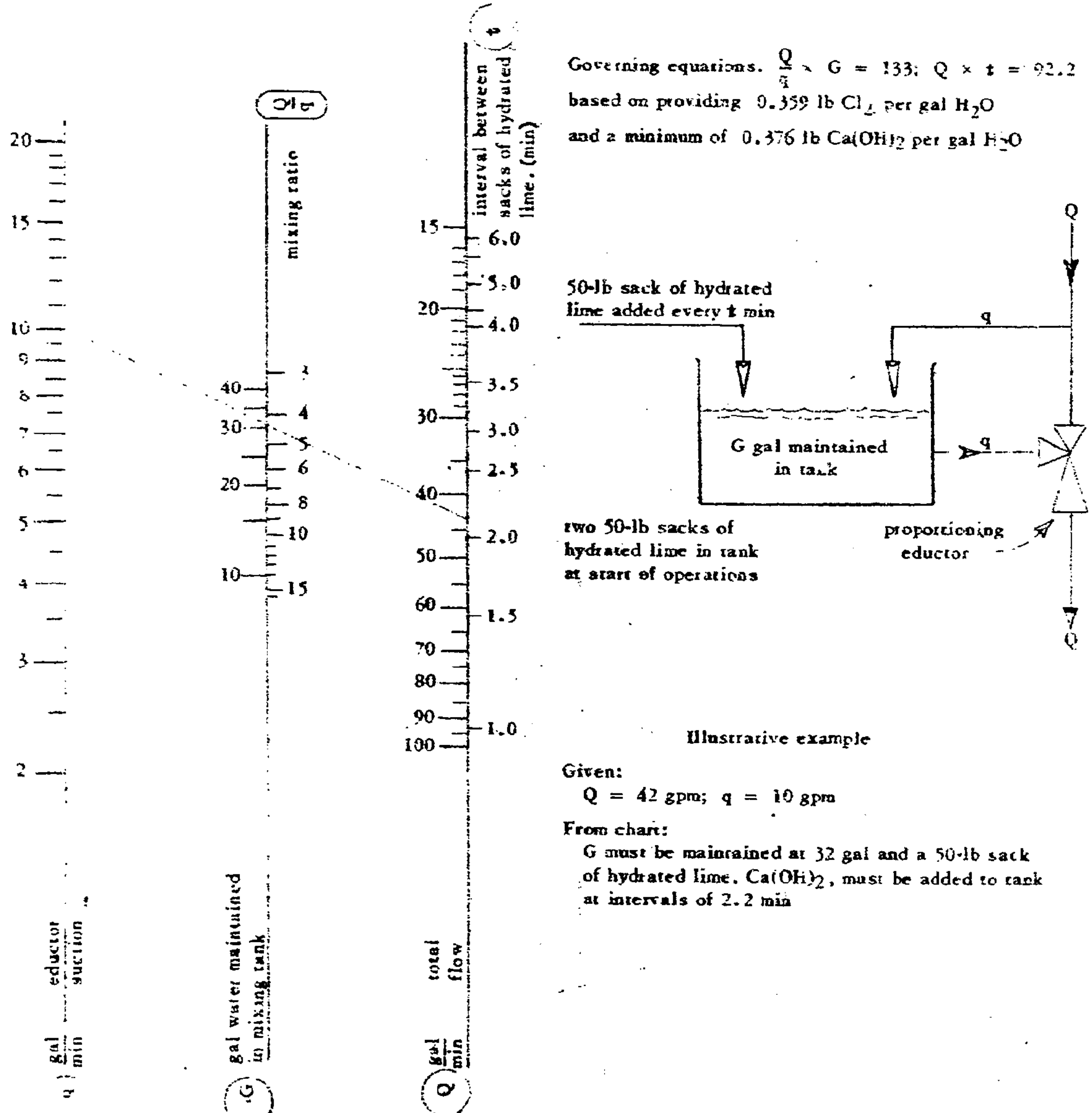



Figure 6. Alignment chart for mixing hydrated lime and water.

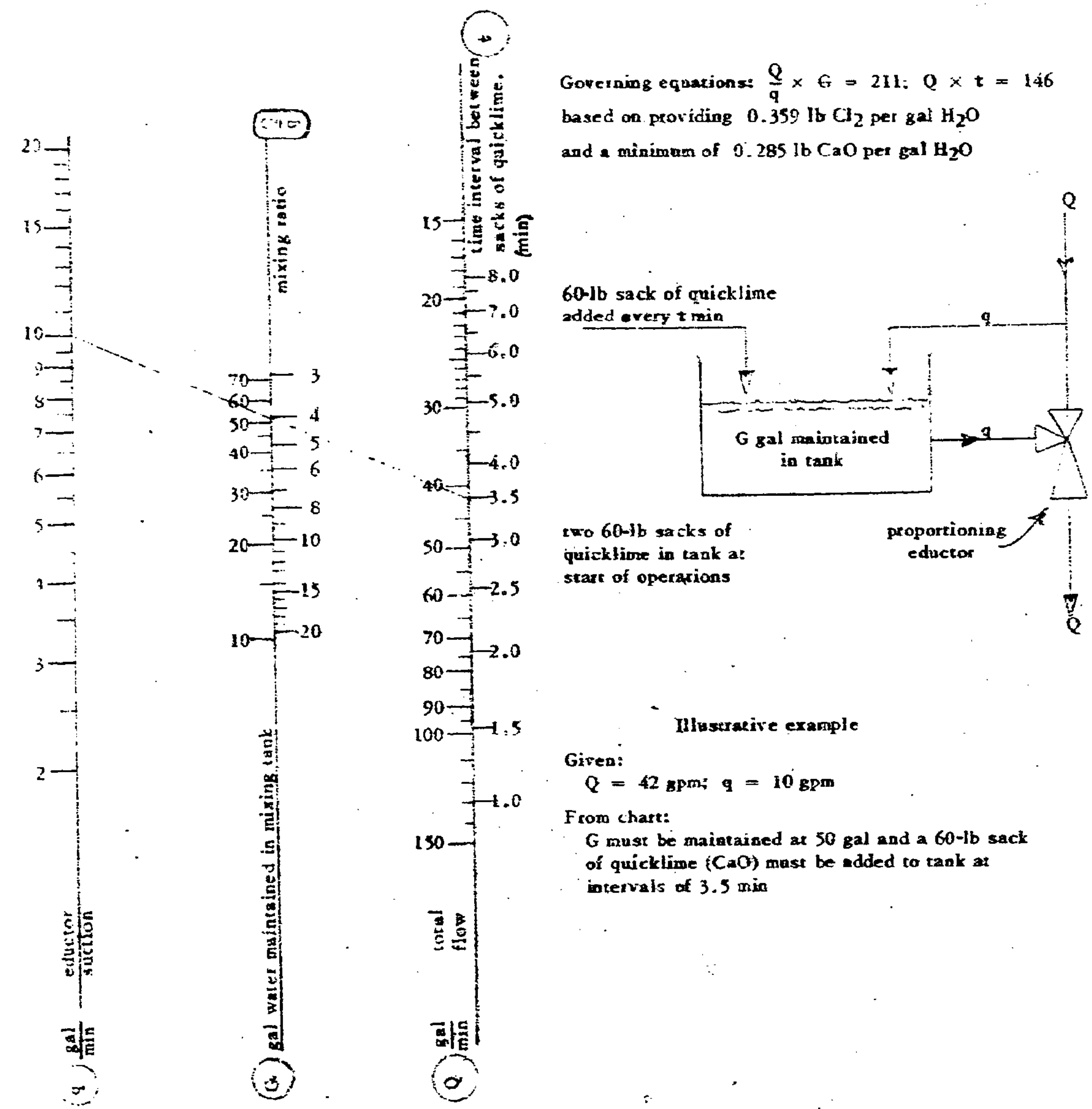



Figure 7. Alignment chart for mixing quicklime and water.

Figure 8. Pouring lime into the mixing unit tank.

Figure 9. Spraying hypochlorite slurry discharge at equipment to be decontaminated.

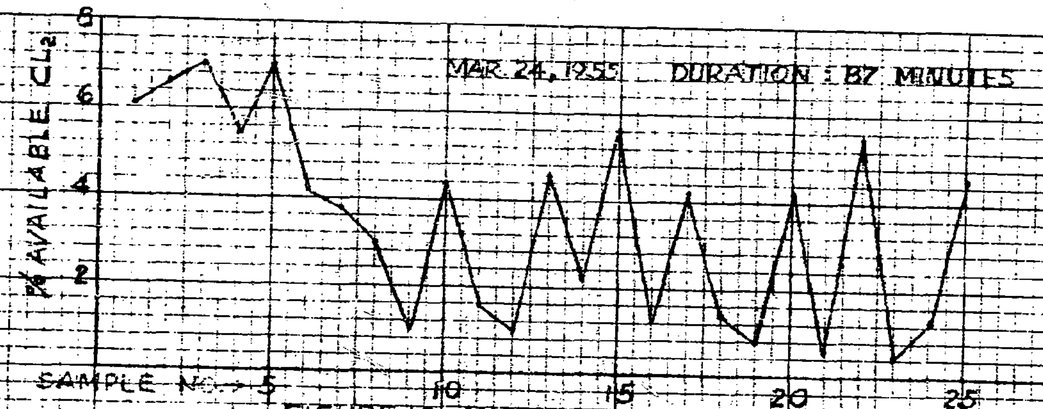


FIGURE 10. ANALYSIS OF 25 TEST SAMPLES

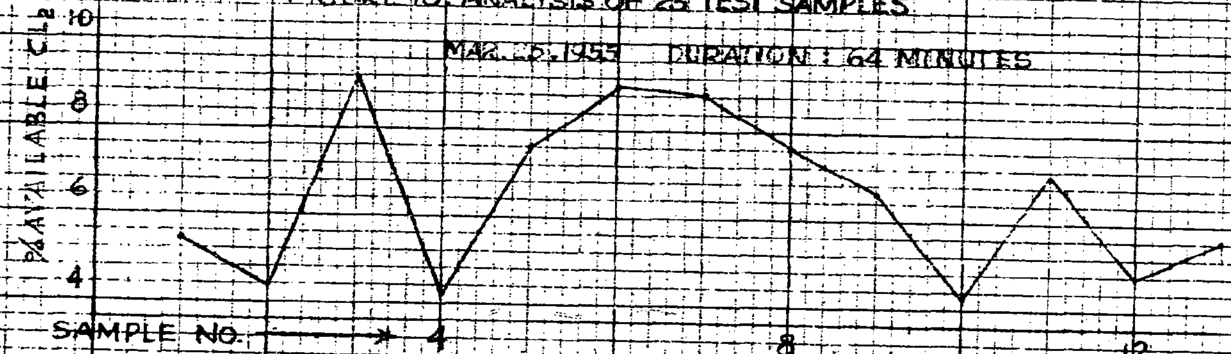


FIGURE 11. ANALYSIS OF 12 TEST SAMPLES

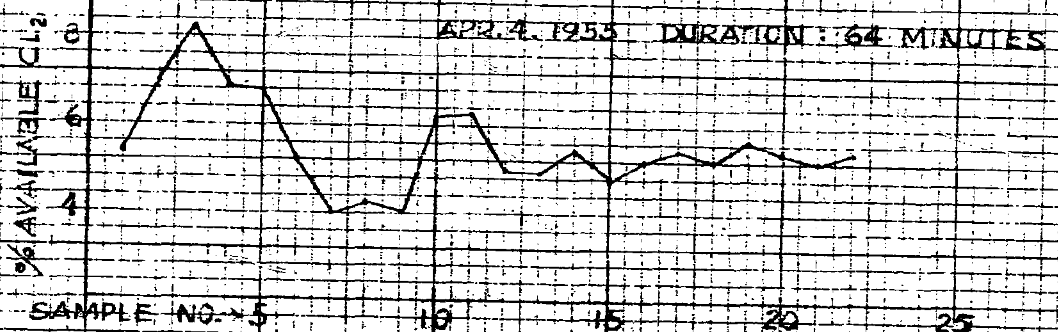


FIGURE 12. ANALYSIS OF 22 TEST SAMPLES

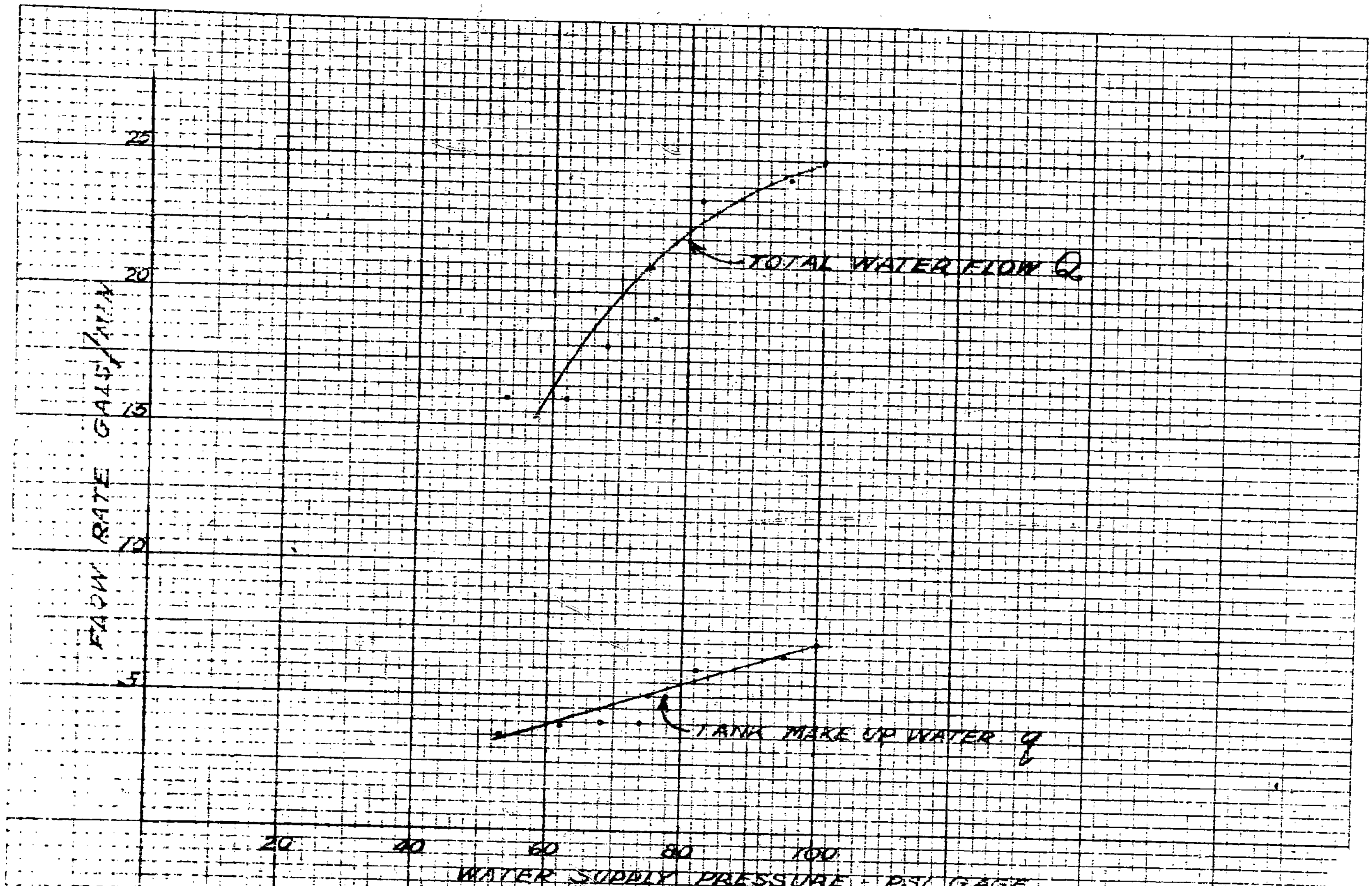



FIGURE 13. OPERATING CHARACTERISTICS OF MATERIALS

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